UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1418

Washington, D. C. ▼ July, 1926

FERTILIZER EXPERIMENTS WITH ALFALFA CONDUCTED AT THE UNITED STATES YUMA FIELD STATION, BARD, CALIF., 1919 TO 1925

By H. L. WESTOVER, *Agronomist, Office of Forage Crops*, and EDWARD G. NOBLE, *Farm Superintendent, Office of Western Irrigation Agriculture, Bureau of Plant Industry*

CONTENTS

INTRODUCTION

The agriculture of the Yuma Reclamation Project has been built up largely around the alfalfa-hay and alfalfa-seed industries. From the beginning these crops have constituted and to a large extent still represent the real backbone of the farming operations. Naturally, when the yields began to decline a few years ago the farmers became much concerned. This led to the need of experimental work to assist in arriving at some satisfactory explanation for the decreasing yields. With this in mind, some rather simple fertilizer experiments were begun in 1919 at the United States Yuma Field Station, Bard, Calif., the results of which indicated the efficiency of available phosphoric acid. Further tests have shown pretty conclusively that phosphoric acid when applied in the form of acid phosphate increases the alfalfa yields sufficiently to render its use very profitable. Some of the details of these tests are presented in the following pages.

HISTORICAL AND STATISTICAL DATA

The agricultural area of the Yuma Reclamation Project comprises about 110,000 acres lying on both sides of the Colorado River in California and Arizona and situated just north of the Mexican line. About 65,000 acres of this land lies in the valley, and before the construction of levees was subject to overflow. The valley soils are alluvial in origin and range in texture from almost pure sand to heavy clay. Except where they are highly impregnated with alkali or else very sandy, the soils in general have been very productive.

Farming was begun in the Yuma Valley about 1890. The early agriculture was confined to the production of grain and alfalfa.

93186°—26

During the first years the water supply was precarious, and the danger from overflow was such as to retard the improvement of the land. Since the construction of the protecting levees by the Reclamation Service in 1906 and with the completion in 1912 of irrigation works which insure an adequate supply of water there has been more diversification of crops, and much improvement has taken place.

Until rather recently alfalfa was by far the most important crop on the project. As Table 1 shows, the alfalfa-hay acreage has constituted at least one-third of the total crop acreage in all years except four. It also led any other crop by a considerable margin until 1918, when it was overtaken by cotton. The cotton acreage was much greater than the alfalfa acreage in 1918, 1919, 1920, and 1924, but the two were about equal in 1921, 1922, and 1923. The combined value of the hay and seed crops of alfalfa exceeded that of any other crop until 1917, when it was surpassed by the cotton crop. Cotton held first place for four years, but was exceeded by alfalfa in 1921 and 1922. In 1923 cotton again assumed the lead and held it through 1924. No other crops in the valley have compared with these two in acreage or value during recent years. The acreage of alfalfa harvested for hay annually, which also includes the acreage devoted to the production of the seed crop a part of the year, has been considerably greater than that harvested for seed, but the total value of the two crops has not varied widely since 1913. In fact, the value of the seed exceeded that of hay in 1915, 1916, 1919, 1920 and 1921.

TABLE 1.—*Acreage, production, and farm values of alfalfa hay, alfalfa seed, and cotton grown on the Yuma Reclamation Project in the 14-year period from 1911 to 1924, inclusive*

[Data furnished by the United States Reclamation Service]

Year	Acreages				Production			Total farm values			Average yield per acre		
		Alfalfa			Alfalfa			Alfalfa			Alfalfa		
	All crops	Hay (total)	Seed	Cotton	Hay (tons)	Seed (pounds)	Cotton (pounds)	Hay	Seed	Cotton	Hay (tons)	Seed (pounds)	Cotton (pounds)
1911	8,570	3,750	2,600	30	16,327	576,730	15,000	$244,905	$92,276	$3,000	4.36	222.00	500.00
1912	11,060	7,269	2,824	25	27,078	814,186	5,800	270,780	81,418	1,160	3.73	288.00	232.00
1913	16,726	10,321	3,388	62	38,100	1,139,100	19,610	287,195	126,450	4,128	3.69	336.00	316.00
1914	22,568	10,426	5,485	2,268	32,525	1,246,318	845,044	196,716	159,806	78,399	3.12	227.00	373.00
1915	25,101	9,441	6,449	709	24,277	1,669,020	359,850	173,297	249,331	39,271	2.57	258.60	507.60
1916	28,283	10,880	8,100	4,670	28,029	2,635,800	2,289,430	266,898	328,725	467,697	2.58	325.20	490.00
1917	35,578	12,901	4,643	12,706	43,177	1,588,500	5,253,454	642,870	262,928	2,280,823	3.30	342.00	413.50
1918	45,049	8,929	4,577	28,608	28,695	1,690,352	10,854,525	565,322	380,216	3,159,634	3.21	369.30	379.40
1919	52,324	11,925	6,425	30,945	31,773	2,350,385	11,027,450	608,558	698,164	4,657,955	2.66	366.00	356.35
1920	54,484	13,000	9,832	37,600	28,862	2,396,013	11,248,000	538,164	646,918	2,153,480	2.22	244.00	299.14
1921	52,390	20,550	13,535	18,425	54,266	3,420,000	4,875,000	430,376	477,970	797,500	2.64	253.00	264.50
1922	53,970	22,735	16,475	21,420	48,333	3,482,665	4,225,000	676,662	522,399	1,056,250	2.13	212.00	197.00
1923	53,050	21,915	15,395	22,110	53,881	3,982,000	7,636,560	640,546	637,120	2,290,968	2.45	259.00	346.00
1924	53,145	17,418	11,507	32,240	42,730	3,591,563	11,660,894	640,840	561,377	2,998,847	2.45	312.00	362.00

In the early years alfalfa fields properly handled produced six or seven cuttings a year, averaging under most favorable conditions nearly a ton per cutting. As early as 1913, Blair [1] reported a con-

[1] BLAIR, R. E. THE WORK OF THE YUMA RECLAMATION PROJECT EXPERIMENT FARM IN 1913. U. S. Dept. Agr., Bur. Plant Indus., West. Irrig. Agr. [unnumbered circ.], p. 18. illus. 1914.

siderable falling off in yields of alfalfa on parts of the project as compared with former years. Where such a condition occurred, it was observed that fields 3 or 4 years old gave the smallest yields of hay. A study of the soil indicated that the decrease in yields was not associated with alkali or a shallow water table, but was associated with a soil that was underlain by pure sand at depths ranging from 14 to 34 inches. Blair suggests that this behavior of the alfalfa may indicate that the crop depends upon the soil to this depth for the first two years, by which time the taproots have reached the sandy stratum where moisture conditions are not sufficiently favorable to support luxuriant growth. He further suggests that on such soils it may be necessary to plow under a crop of alfalfa every two or three years and put the land into a cultivated crop before reseeding to alfalfa.

Several years later complaints were general to the effect that land which had produced satisfactorily previously showed very marked decreases when these fields were plowed, put into some other crop for a year or two, and then sown again to alfalfa. About the same time there were urgent requests for investigations to determine the causes of the apparent decline in yields of alfalfa seed.

That there has been a decline in the yield of alfalfa is revealed by an examination of the statistics of the Reclamation Service which show a yield of 2 to 2½ tons in recent years, as compared with about 3 to 4 tons formerly (Table 1). The seed yields have not declined to the extent generally believed. As a matter of fact, the average yield for 1924 was greater than for 1911. It is true, however, that the yields from 1916 to 1919, inclusive, were nearly 100 pounds greater than since that time, with the exception of the year 1924. For the most part the yields during recent years compare favorably with those for the years 1911 to 1915. Such variations as do occur are doubtless largely attributable to seasonal conditions.

EXPERIMENTAL RESULTS

In an effort to ascertain a possible explanation for the decline in yields, particularly of hay, and for the shorter periods that satisfactory stands survive, a simple fertilizer experiment was begun at the United States Yuma Field Station, Bard, Calif., in March, 1919, on alfalfa that was sown in 1917. The test included duplicate plots receiving acid phosphate and sulphur, and also check plots. The acid phosphate was applied at the rate of 500 pounds and the sulphur at the rate of 200 pounds per acre. In a comparatively short time the effects of the acid phosphate were very marked, whereas the plots that were treated with sulphur showed no improvement over the check plots. During the season the plots receiving acid phosphate produced at the rate of approximately 1 ton per acre more than the check plots, and those receiving sulphur yielded slightly less than the checks. In another test the same year, plots sown that spring and receiving an application of acid phosphate yielded nearly a ton per acre more than the check plots in three cuttings.

In January, 1920, an experiment was started including duplicate plots, one set receiving sulphur at the rate of 150 pounds per acre, another set receiving acid phosphate at the rate of 625 pounds per acre, and a third set receiving barnyard manure at the rate of 11.2

tons per acre. The superiority of the plots receiving acid phosphate was apparent from the first. They yielded at the rate of nearly 2 tons per acre more than the check plots. The manured plots yielded approximately the same as the checks while the plots receiving sulphur fell appreciably below the checks.

In May, 1921, another test was started, including one plot that received acid phosphate at the rate of 400 pounds per acre and another that received 400 pounds of gypsum per acre. After the application of fertilizers, four cuttings were made in 1921 and seven cuttings in 1922. During this time the yield of alfalfa on the plot receiving acid phosphate was practically double that of the checks. Prior to the application of fertilizers, the plot to which the acid phosphate was applied had been the poorest in the series. The gypsum and check plots yielded approximately the same for the entire period.

These preliminary tests indicate that yields of alfalfa may be profitably increased in the Yuma Valley by applications of acid phosphate. This is in line with the view expressed by Hilgard [2] to the effect that many California soils are low in phosphoric acid. He states: "The forecast that for most California soils fertilization with phosphates is of exceptional importance has already been abundantly confirmed by cultural experience." With the exception of stable manure, other fertilizers tried have given no appreciable response. In order to obtain more definite information as to the most profitable rate of application of acid phosphate, a more complete test was begun in 1923 on 20 quarter-acre plots that were sown the previous fall. The fertilizers were applied April 27, 1923. With the exception of the plot receiving 250 pounds of acid phosphate on this date and an additional 250 pounds on October 10 and the manured plots which received manure at the rate of 12 tons per acre in three equal applications of approximately 4 tons each on April 27, June 6, and October 11, the plots have received no fertilizers since the first application.

The 16 per cent acid phosphate was applied at three rates—250, 500, and 750 pounds per acre. The 44 per cent acid phosphate was applied at the rate of 182 pounds per acre, which is equivalent in available phosphoric acid to 500 pounds of 16 per cent acid phosphate. Inasmuch as sulphur has given remarkable increases in yields of alfalfa in parts of the West, applications were made to several plots to determine more definitely the results that might be expected from its use.

The detailed and summarized results of this experiment are given in Table 2.

Although there was an appreciable increase in growth the first year, the big increase in all cases came the second year (fig. 1), after which the yields declined rapidly. Results for 1925 have not been included, as they are not available for the entire year. Two light cuttings were obtained in the early spring and a third light cutting in the fall. During the intervening time the alfalfa was allowed to go to seed, and it is obvious that under such treatment the hay yields would not be representative. The effects of the acid phosphate, however, particularly the heavier applications, were still very apparent. Previous tests indicated that if the acid phosphate had been applied earlier, about the latter part of February

[2] HILGARD, E. W. SOILS, p. 393. 1911.

or the 1st of March, there would have been a much greater increase the first year, though this undoubtedly would have resulted in smaller increases the second year.

TABLE 2.—*Alfalfa yields from various fertilizer treatments at the United States Yuma Field Station, Bard, Calif., in 1923 and 1924*

SEASON OF 1923 (FIRST YEAR)

Fertilizer treatment and rate per acre	Yields of hay per ¼-acre plot (pounds)				Yields per acre (tons)	
	Cuttings			Total	Total	Increase or decrease (−)
	First, June 14	Second, Aug. 14	Third, Oct. 10			
16 per cent acid phosphate (250 pounds)	395	275	320	990	1.980	0.800
Check	185	170	235	590	1.180	
16 per cent acid phosphate (250 pounds in the spring and 250 pounds in the fall)	305	280	298	883	1.766	.732
Check	245	115	157	517	1.034	
16 per cent acid phosphate (500 pounds)	430	415	392	1,237	2.474	1.304
Check	175	185	225	585	1.170	
44 per cent acid phosphate (182 pounds)	420	430	387	1,237	2.474	1.050
Check	215	250	247	712	1.424	
16 per cent acid phosphate (750 pounds)	500	510	398	1,408	2.816	1.672
Check	195	205	172	572	1.144	
Manure (12 tons) plus 16 per cent acid phosphate (250 pounds)	510	625	439	1,574	3.148	1.372
Check	280	275	333	888	1.776	
Manure (12 tons)	470	485	310	1,265	2.530	.420
Check	460	360	235	1,055	2.110	
Texas gulf sulphur (200 pounds)	305	255	180	740	1.480	−.060
Check	285	300	185	770	1.540	
Toro sulphur (200 pounds)	250	170	120	540	1.080	−.320
Check	270	225	205	700	1.400	
Toro sulphur (200 pounds) plus 16 per cent acid phosphate (250 pounds)	455	440	265	1,160	2.320	1.240
Check	205	180	155	540	1.080	

SEASON OF 1924 (SECOND YEAR)

Fertilizer treatment and rate per acre	Yields of hay per ¼-acre plot (pounds)							Yields per acre (tons)	
	Cuttings						Total	Total	Increase
	First, Jan. 11	Second, Apr. 5	Third, May 16	Fourth, June 20	Fifth, Aug. 14	Sixth, Oct. 24			
16 per cent acid phosphate (250 pounds)	180	435	415	385	295	160	1,870	3.740	2.390
Check	35	85	155	170	100	130	675	1.350	
16 per cent acid phosphate (250 pounds in the spring and 250 pounds in the fall)	190	660	555	525	325	220	2,475	4.950	3.520
Check	50	105	140	160	125	135	715	1.430	
16 per cent acid phosphate (500 pounds)	190	390	400	425	290	255	1,950	3.900	2.450
Check	25	95	130	135	145	195	725	1.450	
44 per cent acid phosphate (182 pounds)	240	625	570	610	355	200	2,600	5.200	3.100
Check	45	165	235	235	195	175	1,050	2.100	
16 per cent acid phosphate (750 pounds)	295	800	705	780	545	370	3,495	6.990	4.980
Check	40	140	180	205	185	255	1,005	2.010	
Manure (12 tons) plus 16 per cent acid phosphate (250 pounds)	365	920	810	750	535	480	3,860	7.720	4.550
Check	110	320	275	330	260	290	1,585	3.170	
Manure (12 tons)	305	815	695	790	475	470	3,550	7.100	2.740
Check	185	490	370	485	360	290	2,180	4.360	
Texas gulf sulphur (200 pounds)	105	215	275	350	185	260	1,390	2.780	.390
Check	100	210	265	275	170	175	1,195	2.390	
Toro sulphur (200 pounds)	60	80	170	195	75	305	885	1.770	.426
Check	62	70	105	165	120	150	672	1.344	
Toro sulphur (200 pounds) plus 16 per cent acid phosphate (250 pounds)	162	220	295	295	170	220	1,362	2.724	1.378
Check	53	90	155	115	95	165	673	1.346	

TABLE 2.—*Alfalfa yields from various fertilizer treatments at the United States Yuma Field Station, Bard, Calif., in 1923 and 1924*—Continued

SUMMARY OF INCREASE OR DECREASE IN YIELDS OF ALFALFA FROM FERTILIZED, AS COMPARED WITH UNFERTILIZED PLOTS

[Acid phosphate figured at $38 per ton for 16 per cent, $70 per ton for 44 per cent, manure at $1 per ton, and sulphur at 5 cents per pound]

Fertilizer treatment and rate per acre	Increase per acre (tons)			Approximate cost of fertilizer per acre
	1923	1924	Total	
16 per cent acid phosphate (250 pounds)	0.800	2.390	3.190	$4.75
16 per cent acid phosphate (250 pounds in the spring and 250 pounds in the fall)	.732	3.520	4.252	9.50
16 per cent acid phosphate (500 pounds)	1.304	2.450	3.754	9.50
44 per cent acid phosphate (182 pounds)	1.050	3.100	4.150	6.37
16 per cent acid phosphate (750 pounds)	1.672	4.980	6.652	14.25
Manure (12 tons) plus 16 per cent acid phosphate (250 pounds)	1.372	4.550	5.922	16.75
Manure (12 tons)	.420	2.740	3.160	12.00
Texas gulf sulphur (200 pounds)	−.060	.390	.330	10.00
Toro sulphur (200 pounds)	−.320	.426	.106	10.00
Toro sulphur (200 pounds) plus 16 per cent acid phosphate (250 pounds)	1.240	1.378	2.618	14.75

It is apparent that the effects of the manure are somewhat more lasting than those of acid phosphate, and while sufficient to justify its use where available on the farm, especially as it does not cost the farmer anything other than getting it on the land, the returns will not warrant much cash outlay for the manure.

FIG. 1.—Comparative yields of alfalfa in the Yuma Valley on plots treated with acid phosphate (1 and 3) and on untreated plots (2 and 4)

In line with previous tests, wherever sulphur was applied there was a slight decrease in yield, as compared with the checks the first year and a slight increase the second year. These differences, however, are not great enough to be significant. Sulphur combined with acid phosphate gave an appreciable increase, though considerably less than where the same quantity of acid phosphate was applied alone.

The cost of 16 per cent acid phosphate is about $38 per ton, that of the 44 per cent acid phosphate $70 per ton f. o. b. Yuma, and that of sulphur is 5 cents per pound. No attempt has been made to assign any value to the manure other than the cost of hauling and

spreading, which is figured at $1 per ton. The farm value for alfalfa during these years is placed at $10 per ton, which is probably rather conservative. On this basis, and omitting the cost of hauling and spreading the fertilizer and the added cost of handling the increased yield of hay, the acid phosphate in every case, with the exception of the plot receiving 250 pounds in the spring and an additional 250 pounds in the fall, more than paid for itself the first year. In this instance, however, it is not fair to assess the fall application against the first year, as the alfalfa received no benefit from it until the following year when it increased the yield enough to more than make up for a single application of 500 pounds the previous spring. The greatest increase in yield came from the heaviest application of 750 pounds per acre, but the greatest gain for the money invested came from the lightest application—250 pounds per acre. Disregarding the additional cost of labor involved in this increase, each dollar invested in acid phosphate returned $6.72 in two years. Next to this the most profitable fertilizer application proved to be 44 per cent acid phosphate at 182 pounds per acre. Figured on a similar basis this returned $6.50 for each dollar invested in fertilizer. These results indicate that there is little choice in final results between the two grades of acid phosphate, provided equivalent quantities of phosphoric acid are applied. In all cases the value of the increases in proportion to the money expended in fertilizers was considerably less than this.

This and the preliminary tests indicate rather clearly that where alfalfa is making an unsatisfactory growth on the Yuma project, particularly in those sections where the yields have declined, acid phosphate can be used to very good advantage. Further experimentation is needed to determine the most profitable quantity and the best time to apply it, but since the effects are not very lasting it is believed that an application of 250 pounds about the 1st of March in each alternate year will prove most satisfactory.

EXPERIENCES OF FARMERS

Farmers on the Yuma project visiting the experiment station from time to time have been impressed with the results obtained from application of acid phosphate and have tried it on their own alfalfa fields with such satisfactory results in practically all cases that the demand for the fertilizer has increased each year. Approximately 250 tons of 16 per cent acid phosphate was sold to the project farmers in 1924. This is the equivalent of 250 pounds per acre on 2,000 acres, and it probably has had some influence on the average seed yields for the project, as Table 1 shows.

In most cases this fertilizer has been applied by means of a lime spreader, but considerable difficulty is encountered in adjusting it to spread such small quantities as 300 to 500 pounds per acre. Wherever available, the fertilizer distributor will do better work. In case neither of these implements is convenient, the acid phosphate is spread by hand. In the labor involved the 44 per cent acid phosphate is most economical, but the advantages are in favor of the 16 per cent grade in evenness of distribution because of the heavier applications required.

EFFECT ON SEED YIELDS

Not much work has been done to determine the effect of acid phosphate on seed production, but preliminary tests indicate that its use in this connection will prove nearly as beneficial as it has on the hay crop. In 1925 a crop of seed was taken from the plots that were harvested for hay in 1923 and 1924. As the plots had passed through two whole seasons and part of another, they were beginning to decline, and the effects on seed yields of the various fertilizers applied in 1923 had undoubtedly diminished. Furthermore, the seed yields in this test were materially reduced by considerable shattering as a result of three wind-driven rains that occurred between cutting and threshing. The results, however, are presented in Table 3, since they are believed to be indicative of what may be expected.

TABLE 3.—*Alfalfa seed yields from various fertilizer treatments at the United States Yuma Field Station, Bard, Calif., in 1925*

[Fertilizers applied in 1923]

Fertilizer treatment and rate per acre	Seed yields (pounds)		
	Per ¼-acre plat	Per acre	Increase or decrease (−) per acre
16 per cent acid phosphate (250 pounds)	21.5	86.0	18.0
Check	17.0	68.0	
16 per cent acid phosphate (250 pounds in the spring and 250 pounds in the fall)	24.5	98.0	42.0
Check	14.0	56.0	
16 per cent acid phosphate (500 pounds)	12.5	50.0	−14.0
Check	16.0	64.0	
44 per cent acid phosphate (182 pounds)	20.0	80.0	36.0
Check	11.0	44.0	
16 per cent acid phosphate (750 pounds)	36.2	144.8	58.8
Check	21.5	86.0	
Manure (12 tons) plus 16 per cent acid phosphate (250 pounds)	46.5	186.0	102.0
Check	21.0	84.0	
Manure (12 tons)	59.0	236.0	36.0
Check	50.0	200.0	
Texas gulf sulphur (200 pounds)	29.5	118.0	−4.0
Check	30.5	122.0	
Toro sulphur (200 pounds)	22.5	90.0	14.0
Check	19.0	76.0	
Toro sulphur (209 pounds) plus 16 per cent acid phosphate (250 pounds)	20.5	82.0	
Check	20.5	82.0	

Although the seed yields as given in Table 3 are rather low in all cases, the beneficial results from applications of acid phosphate are very marked. All plots receiving acid phosphate yielded more than the accompanying checks, with the exception of a plot receiving an application of 500 pounds of acid phosphate per acre, which showed an actual falling off. Other factors, however, enter in to explain this apparent discrepancy. The highest yields were obtained from the plots receiving manure and acid phosphate. This is not surprising, since the effects of manure would naturally be expected to be apparent longer than the more soluble commercial fertilizers. The benefits from the use of acid phosphate undoubtedly would have been much more marked if a seed crop had been removed the first or second year after the fertilizers were applied. Sulphur had no effect on seed yields.

In 1922 one demonstration plot receiving 275 pounds of 16 per cent acid phosphate per acre yielded at the rate of 481 pounds of seed per acre, whereas the check plot yielded at the rate of 181 pounds

per acre. Figuring alfalfa seed conservatively at 12 cents per pound, it can readily be seen that the increase in this case gave a handsome profit on an outlay of $5.25 for fertilizer. In addition to this there was a marked increase in the hay crop before and after harvesting the seed.

SOURCES OF SUPPLY OF ACID PHOSPHATE

As the use of fertilizers is relatively new to many of the farmers on the Yuma project, there has been a considerable demand for information as to what acid phosphate is, how it is made, and whether it may have any injurious effects on the soil. For this reason these matters are here briefly discussed.

So far as plant growth is concerned, the essential element in acid phosphate is phosphorus. Alfalfa is generally regarded as being especially heavy in its demands for this element, and it is therefore not surprising that after several years of heavy crop production the addition of phosphoric acid should prove beneficial.

Phosphorus in nature occurs in bones and rocks. At present the supply for fertilizers comes largely from phosphate rocks under the name of acid phosphate.

Acid phosphate is the name generally applied to the product made by treating rock phosphate with sulphuric acid. These rocks have been known in Florida, Tennessee, and South Carolina for some time. More recently large beds have been found in Montana and other Western States. The phosphorus in the rock is practically insoluble and is very slowly available to plants. By treating the rock with sulphuric acid, the solubility of the phosphoric acid is increased so that it becomes more readily available to the plant.

In the manufacture of acid phosphate, the phosphate rocks are finely ground and mixed with sulphuric acid. The mixed mass is allowed to cool and harden, after which it is ground again. In order to avoid the presence of free acid in the acid phosphate the quantity of acid used is somewhat less than that needed to dissolve the phosphate completely, depending upon the composition of the rock. Roughly, about half a ton of sulphuric acid is used in making 1 ton of acid phosphate. There are various grades of acid phosphate on the market, the grade being indicated by the percentage of phosphoric acid. The most common commercial grade contains 16 per cent phosphoric acid. By further treatment of the low-grade acid phosphates, high-grade phosphates known as triple acid phosphates, having approximately 44 per cent phosphoric acid, are obtained. In some cases these high-grade acid phosphates have caused a temporary depressing effect on plant growth, owing to the free acid, but such effects are not often serious and are not permanent. An opinion has been more or less prevalent among farmers that the continued use of acid phosphate is likely to prove injurious to the soil by making it acid. This is probably on account of the name, but as a matter of fact acid phosphate properly manufactured contains no free acid, and tests have shown a decrease rather than an increase in soil acidity through its long-continued use in the East. Since this practice has not resulted in permanent injury there is no apparent reason why there should be any hesitancy in applying it.

SUMMARY

All the tests here cited indicate a marked improvement in the growth of alfalfa from applications of acid phosphate. As between the 16 per cent and the 44 per cent acid phosphate there seems to be little preference, so far as benefit to the alfalfa is concerned, provided equivalent quantities of phosphoric acid are applied. This being the case, it would appear that the farmer should use whichever form is the cheaper, based upon the relative proportions of this element.

Barnyard manure showed some benefit but not enough to justify paying much for it, as the cost of hauling and applying is considerable.

Neither gypsum nor sulphur had an appreciable effect on the yields of alfalfa.

In preliminary tests plats receiving applications of acid phosphate have yielded appreciably more seed than the accompanying checks.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

July 24, 1926

Secretary of Agriculture	W. M. JARDINE.
Assistant Secretary	R. W. DUNLAP.
Director of Scientific Work	
Director of Regulatory Work	WALTER G. CAMPBELL.
Director of Extension Work	C. W. WARBURTON.
Director of Information	NELSON ANTRIM CRAWFORD.
Director of Personnel and Business Administration	W. W. STOCKBERGER.
Solicitor	R. W. WILLIAMS.
Weather Bureau	CHARLES F. MARVIN, *Chief.*
Bureau of Agricultural Economics	THOMAS P. COOPER, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Plant Industry	WILLIAM A. TAYLOR, *Chief.*
Forest Service	W. B. GREELEY, *Chief.*
Bureau of Chemistry	C. A. BROWNE, *Chief.*
Bureau of Soils	MILTON WHITNEY, *Chief.*
Bureau of Entomology	L. O. HOWARD, *Chief.*
Bureau of Biological Survey	E. W. NELSON, *Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Bureau of Dairying	C. W. LARSON, *Chief.*
Fixed Nitrogen Research Laboratory	F. G. COTTRELL, *Director.*
Office of Experiment Stations	E. W. ALLEN, *Chief.*
Office of Cooperative Extension Work	C. B. SMITH, *Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*
Federal Horticultural Board	C. L. MARLATT, *Chairman.*
Insecticide and Fungicide Board	J. K. HAYWOOD, *Chairman.*
Packers and Stockyards Administration	JOHN T. CAINE, *in Charge.*
Grain Futures Administration	J. W. T. DUVEL, *in Charge.*

This bulletin is a contribution from

Bureau of Plant Industry	WILLIAM A. TAYLOR, *Chief.*
Office of Forage Crops	R. A. OAKLEY, *Senior Agronomist in Charge.*
Office of Western Irrigation Agriculture	C. S. SCOFIELD, *Senior Agriculturist in Charge.*

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY